Our thumbs

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The hand without a thumb is at worst nothing but an animated spatula and at best a pair of forceps whose points don't meet properly.*

—JOHN NAPIER (1)

ORIGINS

Our earliest known ancestor is the fish *Rhipidistia* (2), which has been extinct for 230 million years. Its pectoral fin is the precursor of our hand, which has 4 fingers, each with 3 phalanges, and a thumb with only 2 phalanges.

It is known that almost without exception, the first ray of mammals, reptiles and amphibians, and humans had 2 phalanges. Galen (AD 165) thought the bones of the thumb were really 3 phalanges and that it lacked a metacarpal. Vesalius in 1543 agreed, saying that the thumb metacarpal was really a phalanx. Certainly, the position of the growth center, or epiphysis, at the base of the metacarpal matches the position of the epiphysis of all the phalanges. By contrast, the growth center for all finger metacarpals is at their head, while none is present in the thumb metacarpal head.

The fact that the thumb has only 2 phalanges has bothered anatomists for many centuries. Napier settled this discussion when he wrote, "Indeed it is questionable whether it has ever possessed more than 2 phalanges, a conclusion that will no doubt infuriate the legions of anatomists who collectively have expended much time and energy trying to determine whether the missing element of the thumb is a phalanx or a metacarpal" (3). This problem is compounded by the not infrequent occurrence of a triphalangeal thumb, in which the metacarpal has a distal and a proximal epiphysis—an oddity that adds the teratologists to the legions of puzzled anatomists.

The hominids living at the end of the Miocene about 15 million years ago began to develop bipedal locomotion, liberating their hands for independent use. An illustration in John Napier's classic *Scientific American* article "The evolution of the hand" compares the hand bones of a juvenile gorilla, an Olduvai hominid, and modern man (4) (*Figure 1*). Over time, the finger bones have straightened the curvature that was used to grasp tree branches, and the thumb has lengthened and enlarged the size and breadth of its terminal phalanx. The famous "Lucy" is ap-

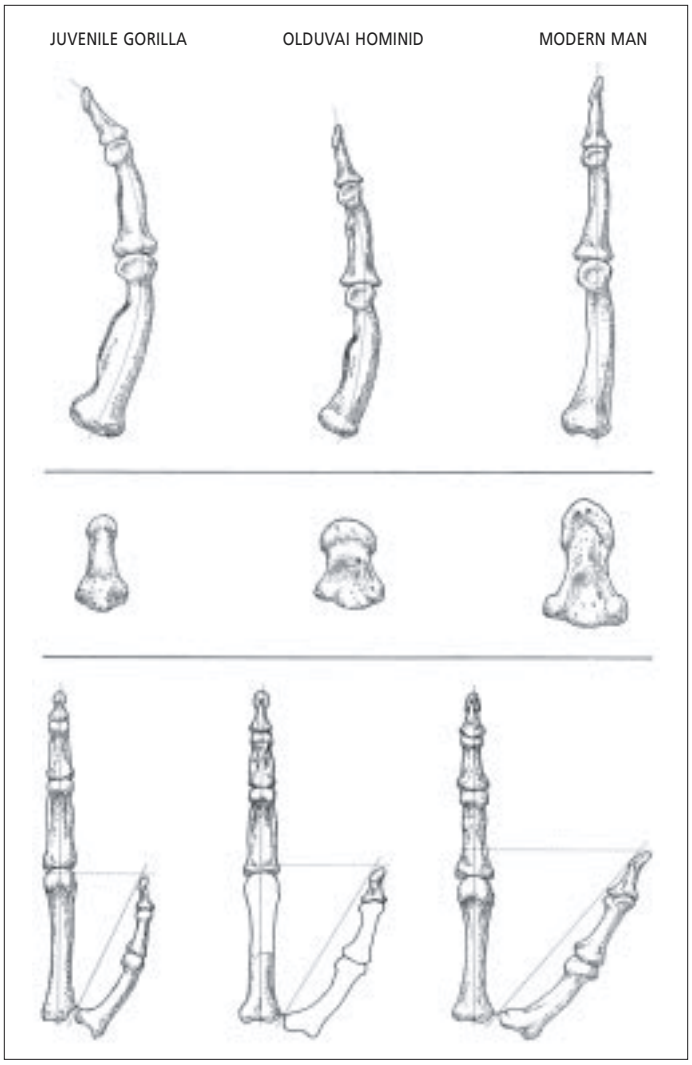

Figure 1. Hand bones of juvenile gorilla, Olduvai hominid, and modern man. **(top, left to right)** The phalanges decrease in curvature. **(middle)** The thumb's terminal phalanx increases in size. **(bottom)** The thumb lengthens, and the angle between index and thumb increases. Reprinted with permission from the estate of the artist, Tom Prentiss, from Napier J. The evolution of the hand. *Scientific American* 1962;207:56–62.

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*I have taken the liberty of translating the original word *fishslice* from British to American English.

proximately 3.5 million years old, and her hand does not have relatively long apelike fingers. They are rather short, and the thumb is fully opposable.

Concomitant with the development of our hand has been an increase in the size of the brain of our early ancestors. Recognizing this, Professor Wood Jones stressed, "The human hand is not a marvel of perfection, but the human brain can command it and control it so that its functional role is immeasurably greater than that of even the most intelligent anthropoid ape" (5). Since the brain knows what it is "commanding," it is significant that the area of the brain devoted to the thumb is much larger than that allocated to a finger. In fact, it is 50% of the cortical area devoted to the hand, while the hand is represented in an area greater than the rest of the arm or the whole of the leg.

The prime importance of the thumb is well shown in compensation schemes for its injury. In AD 616, King Aethelbert in England established the equivalent of a 30% compensation for loss of thumb but only 10% for loss of a finger. Things are not greatly changed today, although total loss of a thumb now rates as a 40% loss of the hand. The total loss of an index or long finger is only 20% of the hand.

DESCRIPTIVE ANATOMY

When looked at from the side, the thumb lies below or anterior to the finger metacarpals and juts out at an angle of 45°. When placed next to the index, its tip does not reach as far as the proximal interphalangeal joint, since it lacks a phalanx and has a short metacarpal; thus from this position, it can readily sweep across the palm and touch the base of the little finger. When the hand is placed palm down on a flat surface, the thumb can also readily lie flat. This versatility of motion is provided by the saddle-shaped carpometacarpal joint at its base.

Gray's Anatomy describes this joint as sellar, or resembling a saddle. Kuczynski expanded this concept in a paper, suggesting that the 2 articular surfaces really resemble the underside of a saddle on the base of the metacarpal and the top of another saddle on the trapezial surface (6) *(Figure 2)*. This configuration and a strong but loose capsule allow an extensive range of motion. The ligaments at the base of the thumb provide its mechanical stability.

FUNCTIONAL ANATOMY

The thumb pillar consists of 3 bones linked by 2 joints poised on a saddle-shaped third joint. The 4 strong gross muscles arising within the forearm place the thumb, while the four smaller muscles wrapped around the thumb metacarpal contribute strength and fine adjustment in thumb posture. This muscle mass used to be called the Mount of Venus but is now better known as the "heel" of the thumb. Each joint contributes specific motions to the articular chain, and each can be affected by the imbalance of its neighbors. This integration of activities implies that destructive changes in one joint will inevitably affect the posture and function of the others. The range of movement of the 3 joints of the thumb shows an astonishing variation among individuals with normal thumbs. The variation in the range of movement at the carpometacarpal joint is not great, but at the other 2 joints it is considerable.

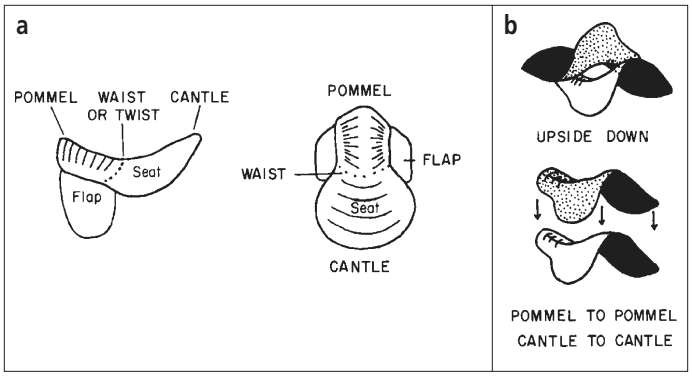

Figure 2. The carpometacarpal joint. **(a)** Parts of a saddle. **(b)** The metacarpal saddle is stippled; solid black shows the undersides of the saddles. The bottom drawing shows the metacarpal saddle with "the right way up" lowered onto the top of the trapezial saddle with pommel to pommel and cantle to cantle. Reprinted with permission from Kuczynski K. The thumb and the saddle. *Hand* 1975;7:120–122.

I used to believe that lack of range of movement at the metacarpophalangeal joint was compensated by an increased range at the interphalangeal joint and that the reverse situation was also true. But I was wrong. The variations in range are extreme. Some double-jointed individuals showed a total range of movement in these 2 joints of more than 300°, whereas others showed a total range between 120° and 130°. Most individuals are unaware that the range of movement of their thumbs is different from that of other people.

The thumb is projected into, and maintained in, space by a balance between the tendons passing over its extensor and flexor surfaces. Since muscle control passes from proximal to distal, the 3-bone longitudinal linkage is subject to the posture of the carpometacarpal joint.

The position of the thumb metacarpal is basically controlled by its enveloping intrinsic muscles, which provide both motion and stability. Several extrinsic muscles cross the carpometacarpal joint, but only the abductor pollicis longus inserts onto the metacarpal. Since this joint is the most proximal of the 3 thumb joints, laxness of its restraints from either ligament destruction or joint collapse sets the stage for articular surface wear and tear, together with zigzag collapse in the more distal joints.

Collapse deformities

Collapse can be initiated by altered or absent tendon forces or by lax capsular structures. It can progress from either the distal to proximal aspect or proximally to distally and occasionally by disturbance of balance in the middle or metacarpophalangeal joint. In the rheumatoid hand, collapse can start anywhere in the chain, but in the osteoarthritic patient, it starts most often in the carpometacarpal joint, occasionally in the interphalangeal joint, and rarely if ever in the metacarpophalangeal joint.

When the carpometacarpal joint is osteoarthritic and the joint surfaces are worn, the joint becomes unstable. Gradually flexion of the joint and adduction of the metacarpal occur. The metacarpophalangeal joint will slowly pass into hyperextension and radial deviation to accommodate prehension. Eventually, the interphalangeal joint will become flexed *(Figure 3)*. Because zigzag collapse is a natural dynamic deformity, balance can be achieved only by restoring the normal tendon forces or by fusing the affected joint, thereby neutralizing the aberrant forces.

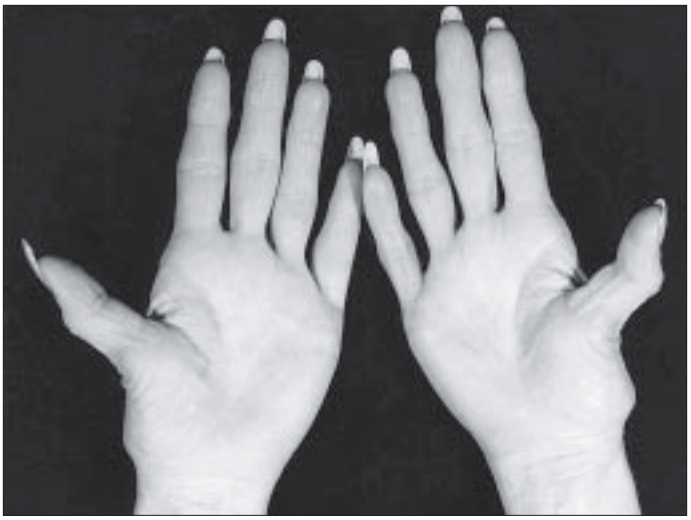

Figure 3. Zigzag collapse. The thumb on the right shows a fully developed collapse deformity. On the left, the carpometacarpal joint is not yet fully dislocated, but collapse has already started in the distal joints.

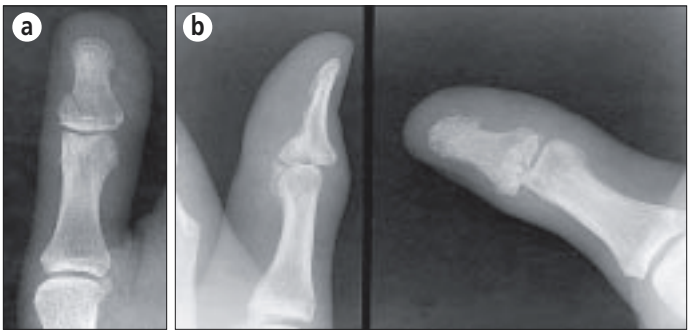

Figure 4. "Sprained thumb." **(a)** An intraarticular fracture of the base of the terminal phalanx. **(b)** The late stage, showing dislocation and osteoarthritis of the joint.

CARE OF THE THUMB

The thumb endures half of the workload of the prehensile hand and is therefore subject to all forms of arthritic changes. In the 3 thumb joints, osteoarthritis occurs most commonly at the carpometacarpal joint; it is next most frequent at the interphalangeal joint. Osteoarthritis is not common at the metacarpophalangeal joint unless it has been subjected to violent or repetitive trauma. One can often fuse 1 or even 2 joints with impunity and also restore function. Various combinations are possible, but it is not equally easy to fuse or replace the various joints.

Interphalangeal joint

Osteoarthritis in this joint is not uncommon and is frequently caused by trauma, which is often dismissed as a sprain *(Figure 4)*. The symptoms should normally be treated by conservative means in the first instance. Use of nonsteroidal antiinflammatory drugs, splinting, occasional intraarticular steroid injections, and modifications in hand usage can be helpful. Ultimately, surgery may be needed. Fusion is the operation of choice; I have never placed a prosthesis in this joint and have never met anyone who readily admits to having done so.

Metacarpophalangeal joint

Primary osteoarthritis of this joint is not common; secondary arthritis following trauma is common. Acute injury, particularly to the ulnar collateral ligament as in the classic "skier's thumb," demands prompt and adequate treatment. If proper treatment is not given, the chronically lax ulnar ligament causes a redistribution of the bearing forces of pinch on the metacarpal head. In time, the wear and tear inevitably lead to degenerative arthritis.

Figure 5. Carpometacarpal osteoarthritis. The joint surfaces are destroyed, the metacarpal is subluxed, and early collapse is shown at the metacarpophalangeal joint.

During the early degenerative changes, it is possible to control the symptoms by medication and splinting; however, these give only temporary relief, and definitive treatment must be planned. Patients fall into 2 basic groups: 1) those who are young and active or 2) those who are middle-aged or elderly and place less demand on their thumbs. For the former group, the only practical treatment is joint fusion; for the latter, prosthetic replacement is an additional option.

Carpometacarpal joint

The carpometacarpal joint of the thumb carries such a heavy workload that it is frequently subject to degenerative changes. In osteoarthritis there may be pantrapezial changes, with involvement of the base of the second metacarpal, the scaphoid, and the trapezoid *(Figure 5)*. Osteoarthritic changes are probably most common in postmenopausal women, but they can also occur in either sex, after Bennett's fracture, or after severe soft tissue injuries to the joint.

The presenting symptom of carpometacarpal joint disease is pain that is poorly localized by the patient. Usually the patient will point either to the dorsum of the web space between the bases of the first 2 metacarpals or to the palmar surface of the thenar muscles. In many instances, the pain is associated with hypermobility of the joint. This hypermobility is more common in women and is probably a major factor in producing degeneration of this joint. Persistent hypermobility predisposes to joint

trauma and increasing damage to the articular surface. Symptoms usually begin with a painful synovitis in the dominant thumb during the fifth decade of life. In the early stages, the synovial proliferative swelling around the base of the thumb can sometimes be seen and can always be palpated. Traction on the thumb and rotation of the metacarpal will compress the swollen synovium and produce pain. In later stages when the articular surfaces are worn, pain is produced by the opposite maneuvers of compressing the joint and rotating the metacarpal—the so-called grind test.

If the patient presents with late disease, combining the grind test with passive reduction of the dorsally subluxed joint will produce pain and crepitus—a virtually diagnostic test. An important part of the physical examination should be the measurement of pinch strength. The pinch strength of the average woman is about 15 to 17 lb; of the average man, about 25 lb. When these figures are only mildly reduced, conservative care may be indicated.

Monitoring the pinch strength over time is a useful measure of disease progression. If the poundage of pinch strength drops into single figures, conservative care has probably reached its limit. When conservative care is unacceptable to the patient, either because it has not helped or because it interferes with essential activities, then surgery is needed. However, the patient must understand that the operation cannot restore full and normal pinch strength.

SURGICAL OPTIONS

A detailed description of the many procedures used for the arthritic thumb is not suitable for this essay. In this article, I offer my current views on the "best" operations. As always, it depends on the patient's needs and the judgment of the surgeon.

Fusion

Stability is more important for useful function of the thumb than for movement, particularly at the metacarpophalangeal and interphalangeal joints. If a good range of motion is present in these joints, the vital carpometacarpal joint can be fused for localized destruction, provided there is no pantrapezial involvement. There is no strict age range to determine when fusion should be done. The decision depends on the patient's functional demands, not the calendar. The "low-demand" patient does better than one who needs a highly active thumb.

Whatever method of fusion is selected, it is the final position that is important. There is general agreement that the most functional position is that in which the thumb lies against the middle phalanx of the index finger in the grasped fist posture.

I believe there is a definite use for fusion in the carpometacarpal joint, particularly in younger age groups. In older patients, I do not hesitate to recommend an arthroplasty operation if I am concerned about the presence of scaphotrapezial or pantrapezial arthrosis.

Arthroplasty

An early account of excisional arthroplasty for carpometacarpal joint arthritis was published in 1949. Gervis reported 18 operations on 15 patients in whom the trapezium was totally excised (7). They did so well that 24 years later, Gervis did a follow-up study of "perhaps a hundred operations." Included was his own right carpometacarpal joint; excision of his trapezium allowed him to "operate and indulge in hobbies in comfort." He reported that his occupational therapy consisted of remaking the wooden back wheel of a gypsy caravan.

In the early 1960s, Froimson "developed tendon interposition arthroplasty to improve on Gervis' original concept by introducing a ball or 'anchovy' of tendon material into the space left . . ." (8). Subsequently, different materials have been used for such fillers, including palmaris longus or portions of the flexor carpi radialis tendon, cadaveric allograft fascia lata, Achilles tendon, silicone rubber, Gore-Tex, and Gelfoam sponge.

Excision of the trapezium with prosthetic replacement can provide stability and acceptable motion. Each implant device has its supporters, and the indications for their use appear to overlap. A study of trapeziectomy in a comparable series of 45 patients did not show any significant difference between the results obtained by an "anchovy" tendon implant and a silicone rubber replacement. Burton and Pellegrini do not use silicone implants in the osteoarthritic hand, and their ligament reconstruction with tendon interpontion arthroplasty has become a preferred treatment for advanced basal joint osteoarthritis (9). I believe that there is little difference between silicone implants and tendon spacers, but as it is now, there will be an increasing use of soft tissue procedures rather than the implanting of man-made materials.

No matter which type of procedure is used for retaining motion at the basal thumb joint, meticulous restoration of the ligamentous supports of the joint is essential. In early degrees of joint instability, ligamentous reconstruction may well be sufficient.

BIRTH DEFECTS

Even in the best of times, our thumbs come short or long, fat or thin, adducted or abducted, stable or wobbly, and even split into two or more—despite all this, most of them work reasonably well. So they should since they are virtually half of a functioning hand. However, it is not uncommon to find these "differences" at birth. In my own series of 2758 children with congenital hand defects, just over 400 babies had abnormalities of a thumb, for an incidence of 14.5%. Many defects are associated with syndromes, particularly short thumbs. These so-called stub thumbs have acquired a variety of labels, including potter's thumb and murderer's thumb. In some thumbs the metacarpal is short and broad; in others, it is hypoplastic. The proximal phalanx may be broad as well as short, or it can be slender and hypoplastic.

An absent thumb

Absent thumbs and the more common hypoplastic thumbs occur in many syndromes and are a signal for careful examination by a pediatrician since some are associated with severe cardiac anomalies. Care of these should take priority.

John Napier has stressed that "without a thumb the hand is put back 60 million years in evolutionary terms" (1). When an adult loses a thumb through trauma or disease, experience in the past half-century shows that *the* operation to restore function is pollicization of the index finger. This transfer presupposes that a small stub of the metacarpal base is present, onto which the

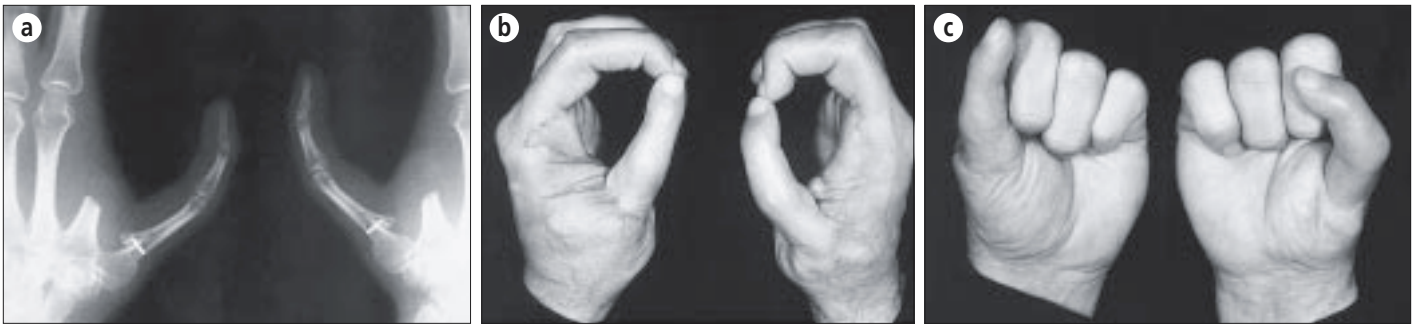

Figure 6. Pollicization. An electrical accident burned off both thumbs in this adult man. **(a–c)** Three different views of the transposition of both index fingers, which restored grasp. The man returned to work on power lines.

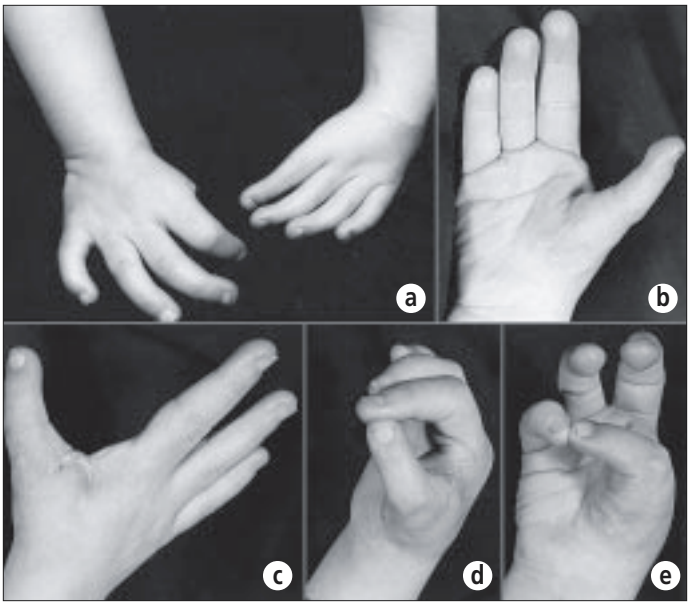

Figure 7. Pollicization in childhood. **(a)** This child had early stabilization of her left radial clubhand by ulna implantation at 18 months of age. She had no right thumb, and pollicization was done a year later. **(b, c)** The posture and size of the new thumb. **(d, e)** Lateral pinch and full opposition are possible. Reprinted with permission from Flatt AE. *The Care of Congenital Hand Anomalies.* St. Louis, Mo: Quality Medical Publishing, 1994.

base of the proximal phalanx can be fixed. When both thumbs are lost, bilateral pollicization will transform the hands from mere hooks to prehensile organs *(Figure 6)*.

The child born with an absent thumb is a cause of great concern for the parents, who must be helped in dealing with their feelings of grief, responsibility, and guilt. (Grandparents are often an additional problem!) It is not proven that these children will later have some degree of psychological impairment, but there is general agreement among hand surgeons that when a thumb is absent, pollicization should be done in the first year of life.

The timing of surgery is important, and experience has shown that, in general, "the earlier the better." A baby cares little about its thumb during the first 3 months of life. It then becomes an important comforter until about 6 to 8 months of age, when opposition begins to develop. Problems arise when one hand is normal and naturally assumes the prehensile tasks. This lets the hand with an absent or abnormal thumb languish or develop strange and different patterns of grasp. If these habit patterns are allowed to imprint on the cortex, rehabilitation after reconstructive surgery may be difficult. In such cases, I occupy the "good" hand with a favorite toy or even restrain it after placing food within the child's reach. A thumbless hand has a very hard time getting any food to the mouth *(Figure 7)*.

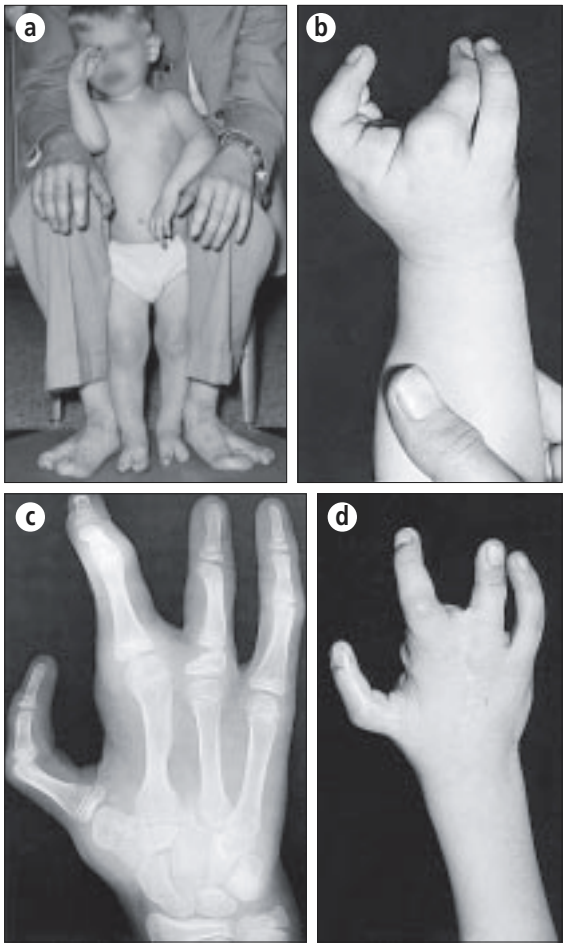

Figure 8. Triphalangeal thumb–associated anomalies. **(a)** This adult with bilateral triphalangeal thumbs and cleft feet fathered this child with cleft feet, cleft hands, and syndactylism of triphalangeal radial digits. The operative plan for the child included separation of the syndactyly **(b)** and closure of the cleft, osteotomy of the long finger metacarpal, and pollicization of the index **(c, d).** The result is a far-from-normal but very functional hand. He subsequently grew up and has fathered a son with perfectly normal hands and feet. Reprinted with permission from Flatt AE. *The Care of Congenital Hand Anomalies.* St. Louis, Mo: Quality Medical Publishing, 1994.

In an infant born without both thumbs, the only practical operation is bilateral pollicization. Not unreasonably, parents are

Figure 9. Floating thumb and pollicization. **(a)** Both of these useless thumbs were replaced by pollicization. Amputation of the thumb and transfer of the index were done at the same time; this demands very careful planning of the skin flaps. **(b, c)** One year after the first pollicization and 6 months after the second, the patient had good span and good strength. Reprinted with permission from Flatt AE. *The Care of Congenital Hand Anomalies.* St. Louis, Mo: Quality Medical Publishing, 1994.

loath to consider what to them seems to be a radical mutilating procedure. It has been my practice to always introduce the family to a child who has had pollicizations. Watching both children play with identical toys usually convinces the parents of the value of the operation.

I do the operation when the child is about 6 months of age. The child must first be thoroughly examined by a pediatrician, who may identify a variety of syndromes that are frequently associated with absence of the thumb or even other thumb deficiencies. Reconstructive surgery for these abnormalities has greatly improved in recent years but should always be dependent on expert anesthesia.

A thumb too long

Too long a thumb, as in a triphalangeal thumb, makes a clumsy, grotesque-looking digit. It cannot function well because its tip is too near those of the fingers *(Figure 8)*. Removing the extra phalanx or shortening the thumb by excising what is, in this digit, the proximal interphalangeal joint and fusing 2 shortened phalanges together provides a good-looking thumb of more practical length.

A floating thumb

When a thumb is slender, unstable at its base, and attached by a skin tag, it is called a "floating thumb." These scrawny little thumbs are usually placed too far distally and too far radially to provide reasonable opposition even if a stable base could be provided. They lack extrinsic and intrinsic muscle control and usually have only a single neuromuscular bundle. Unfortunately, parents often develop a marked attachment to these rudimentary thumbs, particularly if small degrees of jerky movements can be seen as if tendons were working. I have explored a number of these thumbs and have never found adequate tendons. These unsightly and useless thumbs should be removed and the index finger pollicized *(Figure 9)*. A word of caution: Japanese parents and those of several Far Eastern countries rarely accept pollicization for their child. A normal number of digits on the hand is usually more important to them than a properly functioning thumb. Toes do not seem so important to parents, and as an alternative, a normal carpometacarpal joint can be supplied with a proper length thumb by transfer of the second toe. This can be done by an experienced surgeon when the child is around 6 months of age and certainly before his or her first birthday (10).

Too many thumbs

Polydactyly of the thumb is its most common aberration; in my series of 2758 children with congenital hand defects, there were 184 cases, representing nearly 7% of all diagnoses *(Figure 10)*. Commonly called a duplication, it is best considered as a splitting of the thumb into 2 digits. Ezaki of the Texas Scottish Rite Hospital for Children has emphasized that *duplication* implies an excess of tissue and an expectation that the final result may be normal or even better (11). Surgical correction of the many variations of polydactyly is far from simple. The duplications are usually classified into 6 different types. Each type has its own technical problems, all of which demand experience and good judgment. The resultant thumb is always smaller than the normal size, and its joints are usually stiffer.

Webbed thumb

Syndactyly is the most common of all congenital diagnoses in the hand. Syndactyly of the thumb to the index finger is less common than syndactyly among the fingers. Because of the difference in length, the union between the 2 tips must be separated early to prevent a permanent flexion contracture of the index finger. A lot of skin needs to be supplied to liberate the thumb into opposition.

Trigger thumb

Trigger thumb in infants and young children is not common, but it is significantly more common than trigger finger in children. In about 30% of cases, it is self-curing soon after birth; a further 10% to 12% resolve when the child is between 6 months and 3 years of age. After this, surgical release is needed. The operation is simple if care is taken to protect the 2 subcutaneous digital nerves, which lie close to the tendon sheath. The tendon nodule should not be excised; it will resolve over time.

Infants normally clasp their thumbs during their first few weeks of life and continue until about the third month. If the thumb is adducted and remains flexed at the interphalangeal joint and even the metacarpal joint, then the diagnosis is not likely to be a trigger thumb but the rare occurrence of a congenital absence of the extensor pollicis longus tendon. Extensive surgery may be necessary to restore full function to the thumb.

In adults, established trigger thumb should always be treated surgically. *Figure 11* illustrates a woman in her 40s and her son, both with trigger thumbs. As a child, the mother had been told

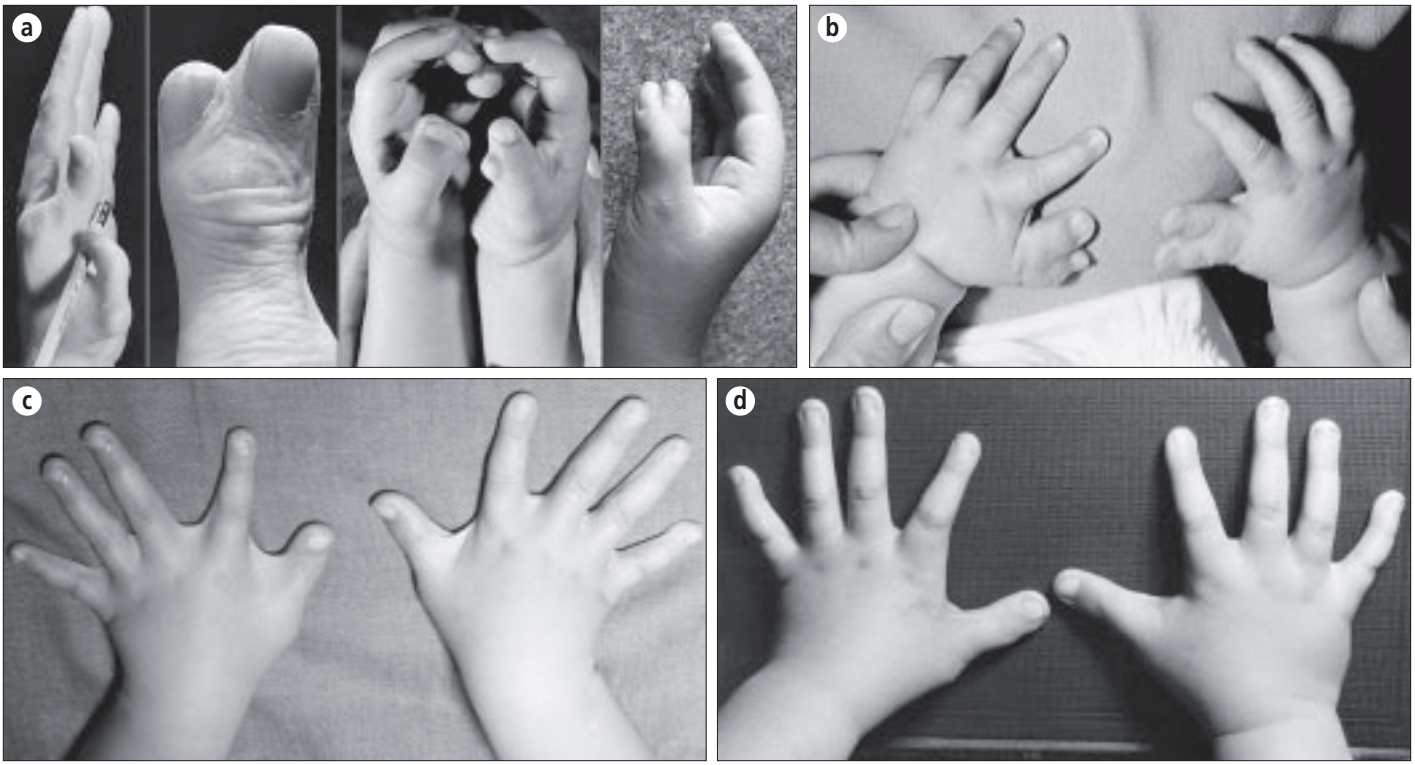

Figure 10. Extra thumbs. **(a)** In this most common polydactylism, there is a complete reproduction of the proximal and distal phalanges. As in other types, there is a tendency for one thumb of the pair to be larger. **(b)** When parallel thumbs are present, a choice has to be made as to which to retain; I always plan generous skin flaps at the expense of the discarded thumb. **(c)** When the web space needs deepening, I usually do it at a later operation so as to avoid vascular embarrassment by operating on both sides of a thumb simultaneously. **(d)** Thirteen years later, the result remains satisfactory in the teenaged patient. Reprinted with permission from Flatt AE. *The Care of Congenital Hand Anomalies.* St. Louis, Mo: Quality Medical Publishing, 1994.

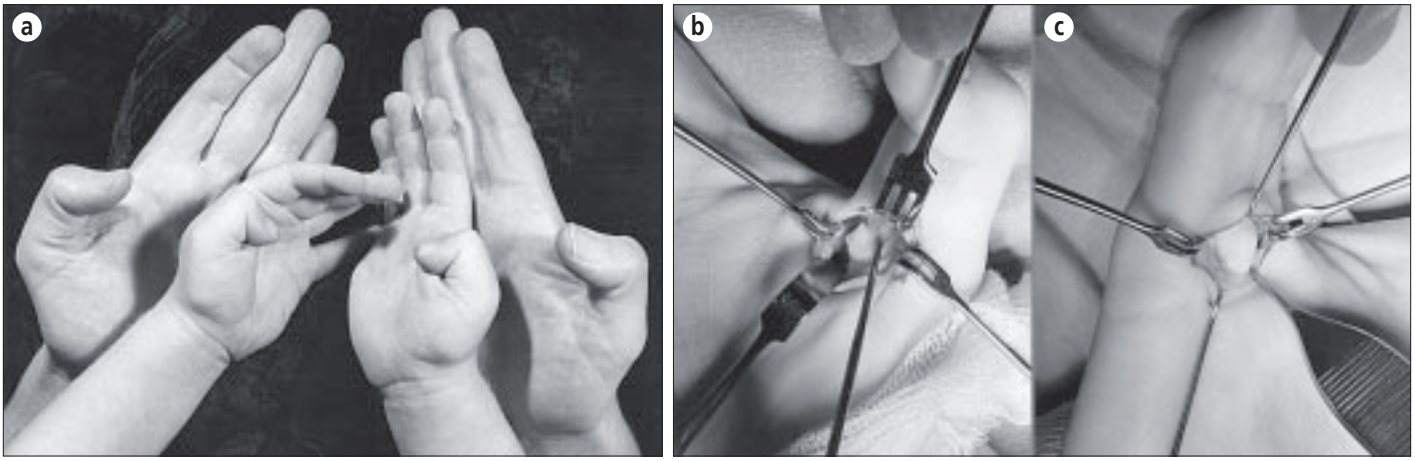

Figure 11. Trigger thumb. Congenital trigger thumb is occasionally inherited and is more common than trigger finger in children. **(a)** A mother and her son with trigger thumbs. As a child, the mother was told surgery would be too dangerous. The mother's right thumb **(b)** and her son's left thumb **(c)** during surgical release. Note the large irregular nodule in the mother's thumb. Reprinted with permission from Flatt AE. *The Care of Congenital Hand Anomalies.* St. Louis, Mo: Quality Medical Publishing, 1994.

that the operation was too dangerous to risk; I released all 4 trigger thumbs with no untoward result.

A NEW THUMB AFFLICTION

In a recent article in the *Wall Street Journal*, Geoffrey Fowler reports an increasing problem for our thumbs (12). In this age of handheld electronic gadgets, the thumb is called upon to punch buttons or keys innumerable times each day. A whole new language is growing up around it; *Nintendothumb* or *Nintendinitis* in children has been reported in the *New England Journal of Medicine*. Adults using mobile phones punch out numbers with their thumbs and develop synovitis in their carpometacarpal joints.

Virgin Mobile, a telecom network in the United Kingdom, records that British thumbs type more than 1.4 billion text messages each month. Many of these messages may suffer from a "splat problem," which occurs when adult thumbs hit more than 1 key at the same time. With increasing miniaturization of these gadgets, splattering inevitably increases. The company that makes the Blackberry handheld personal digital assistant, or PDA, says that its keys are oblong-shaped to maximize the sur-

face area for the thumb. It is said that the way to avoid splat is to train oneself to use only the tip of the thumb. Experienced users, employing both thumbs ambidextrously, are said to be able to input up to 40 words a minute.

Inevitably, the spectre of repetitive stress injury has arisen. A barrister in London considers himself a victim of text message injury (TMI): spending 4 years punching out more than 500 messages per month resulted in serious pain in his thumb joints. Virgin Mobile together with the British Chiropractic Association recommends a series of hand-squeezing exercises using a foam rectangle called a texterciser—the program is offered under the title *How to Practice Safe Text*.

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